MULTISCALE MODELING IN ELECTROTECHNICS: HOMOGENIZATION TECHNIQUES

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ABSTRACT

The behavior and performance of electromagnetic AC devices may be considerably altered by the eddy currents in its laminated iron cores as well as by skin and proximity effect in its windings. This is the case in e.g. power electronic applications where working frequencies and harmonic distortion are constantly increasing. Neglecting these effects in the resolution stage of the FE modeling of e.g. an electrical machine, possibly followed by an a posteriori loss estimation, may then be insufficient for certain design aspects. The eddy-current effects should be accounted for in the early stages of the design. For real-life machine geometries, the 2D or 3D modeling of the individual laminations and turns is normally excluded because of the huge computational cost. Alternative methods are thus indispensable. Homogenization methods are then a viable alternative.

Many techniques have been successfully applied for dealing with lamination stacks in finite-element models: non-conducting and homogeneous stacked core with *a posteriori* loss estimation, anisotropic surrogate material laws, embedded lower dimensional models, multiscale computational homogenization techniques, ... We will pay particular attention to so-called one-step homogenization techniques, accounting for nonlinear and hysteretical material laws. They are based on a polynomial expansion of the variation of the induction throughout the thickness of an individual lamination and further embedded in a magnetodynamic finite-element formulation. Multiscale computational homogenization techniques will be considered as well. The multiscale approach presented in is built up within the heterogeneous multiscale method framework. It couples: 1) a macroscale problem that captures the slow variations of the overall solution; 2) many microscale problems that allow determining the macroscale constitutive law. Particular attention will be paid to local data.

As for windings, skin and proximity effects are accounted for by adopting a complex impedance in the electrical circuit and a complex reluctivity in the homogenized winding domain, respectively. The frequency dependence of these complex quantities is obtained either analytically or using an elementary FE model. Round conductors with rectangular packing are mostly studied. We consider a more general approach, i.e. a multiturn winding of periodically spaced conductors of arbitrary but symmetric cross section. Furthermore, the frequency-domain skin and proximity coefficients are converted into time-domain equations, where again a certain order has to be fixed considering the relevant frequency interval.